voltage different from platen **14**, while mask **100** minimizes any disturbance to plasma **40** caused by the presence of Faraday cup **104**. A mask of this type may be used in any configuration that uses one or more Faraday cups as described herein.

Another Faraday cup configuration is shown in FIG. **6**. A Faraday cup assembly includes an electrode **110** positioned between a mask **112** and the entrance to a Faraday cup **114**. Electrode **110** and mask **112** each have an opening aligned with the entrance to Faraday cup **114**. The mask **112** is preferably maintained at the electrical potential of platen **14**. Electrode **110** is connected to a voltage source **120** which provides a voltage selected to suppress escape of secondary electrons from Faraday cup **114**. The electrode **110** provides electrostatic suppression of secondary electrons and may have a beneficial effect in suppression of hollow cathode discharges. Electrons escaping from the Faraday cup introduce errors into the measured ion dose.

Another Faraday cup configuration is shown in FIG. **7**. A Faraday cup assembly includes magnets **130** and **132** positioned between a mask **134** and an entrance to a Faraday cup **136**. The mask **134** and magnets **130**, **132** define an opening aligned with the entrance to Faraday cup **136**. The mask **134** may be maintained at the same electrical potential as platen **14**. The magnets **130** and **132** produce magnetic fields at the entrance of Faraday cup **136** which suppress escape of secondary electrons. The magnets **130** and **132** provide magnetic suppression of secondary electrons.

Another Faraday cup configuration is shown in FIG. **8**. A Faraday cup **150** has a geometric configuration that inhibits escape of secondary electrons. In particular, the interior depth D of Faraday cup **150** is large in comparison with the width W of Faraday cup entrance **152**. In this configuration, secondary electrons generated at a bottom surface **154** of Faraday cup **150** have a relatively small probability of escaping through entrance **152**.

Another Faraday cup configuration is shown in FIG. **9**. A Faraday cup assembly includes a secondary electron collector ring **170** disposed between an entrance aperture plate **172** and an ion collector plate **174**. The secondary electron collector ring **170** is insulated from entrance aperture plate **172** by an insulating washer **176**, and is insulated from ion collector plate **174** by an insulating washer **178**. The secondary electron collector ring **170** may be maintained at a potential of about 10–100 volts positive with respect to ion collector plate **174** by a voltage source (not shown) or by a voltage divider (not shown) connected between the cathode and anode potentials. By preventing secondary electrons formed at the ion collector plate **174** from moving toward the Faraday cup entrance, this configuration is effective in preventing a hollow cathode discharge from occurring. The secondary electron current flowing to the secondary electron collector ring **170** must be subtracted from the current measured by the ion collector plate **174** in order to obtain the desired net ion current, which is a measure of dose.

In each case, the Faraday cup assembly, including the Faraday cup and associated elements, if any, is preferably positioned adjacent to platen **14** and wafer **20**. The top surface of the assembly is preferably coplanar or nearly coplanar with the top surface of wafer **20**. The Faraday cup assembly is configured to minimize any disturbance to plasma **40** which could adversely effect both ion implantation into wafer **20** and measurement of ion current by the Faraday cup assembly.

The invention has been described thus far in connection with a plasma doping system in which a plasma is formed

upon the application of a high voltage pulse between platen **14** and anode **24**. One or more a Faraday cups may also be utilized in a plasma immersion system wherein a plasma is present continuously in the region between the anode and the cathode, and ions are accelerated toward the cathode by application of a high voltage pulse.

In the configuration of FIG. **1**, anode **24** is separate from but electrically connected to chamber **10**. In other configurations, the conductive walls of the plasma doping chamber **10** may serve as anode, and a separate anode is not utilized.

While there have been shown and described what are at present considered the preferred embodiments of the present invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the scope of the invention as defined by the appended claims.

What is claimed is:

1. Plasma doping apparatus comprising:
   - a plasma doping chamber;
   - a platen mounted in said plasma doping chamber for supporting a workpiece, said workpiece constituting a cathode;
   - a source of ionizable gas coupled to said chamber, said ionizable gas containing a desired dopant for implantation into the workpiece;
   - an anode spaced from said platen;
   - a pulse source for applying high voltage pulses between said platen and said anode for producing a plasma having a plasma sheath in the vicinity of said workpiece, said plasma containing positive ions of said ionizable gas, said high voltage pulses accelerating said positive ions across the plasma sheath toward said platen for implantation into the workpiece; and
   - a Faraday cup positioned adjacent to said platen for collecting a sample of said positive ions accelerated across said plasma sheath, said sample being representative of the number of positive ions implanted into the workpiece.

2. Plasma doping apparatus as defined in claim **1** further comprising means for maintaining said Faraday cup and said platen at substantially equal electrical potentials.

3. Plasma doping apparatus as defined in claim **1** further comprising an electrically conductive mask having an opening aligned with said Faraday cup and means for maintaining said mask and said platen at substantially equal electrical potentials.

4. Plasma doping apparatus as defined in claim **1** wherein an entrance to said Faraday cup is substantially coplanar with the workpiece.

5. Plasma doping apparatus as defined in claim **1** wherein said Faraday cup comprises a plurality of Faraday cups disposed around said platen.

6. Plasma doping apparatus as defined in claim **1** wherein said Faraday cup comprises an annular Faraday cup disposed around said platen.

7. Plasma doping apparatus as defined in claim **1** further comprising a guard ring disposed around said platen, wherein said Faraday cup is positioned within said guard ring.

8. Plasma doping apparatus as defined in claim **1** further comprising a guard ring disposed around said platen, wherein said Faraday cup comprises a plurality of Faraday cups positioned within said guard ring, and further comprising means for maintaining the Faraday cups at the same potential as the guard ring to suppress capacitive contribution to the measured current.

9. Plasma doping apparatus as defined in claim 1 further comprising a guard ring disposed around said platen, wherein said Faraday cup comprises an annular Faraday cup positioned within said guard ring, and further comprising means for maintaining the annular Faraday cup at the same potential as the guard ring to suppress capacitive contribution to the measured current.

10. Plasma doping apparatus as defined in claim 1 wherein said Faraday cup generates an electrical current representative of the number of positive ions implanted into the workpiece per unit time and wherein said apparatus further comprises a dose processing circuit for integrating said current with respect to time and generating an output representative of the dose of positive ions implanted into the workpiece.

11. Plasma doping apparatus as defined in claim 1 wherein said Faraday cup comprises a plurality of Faraday cups disposed around said platen, each producing a current representative of the number of positive ions implanted into the workpiece per unit time and wherein said plasma doping apparatus further comprises a dose uniformity circuit for comparing the currents produced by said plurality of Faraday cups and generating in response to the comparison an output indicative of the uniformity of ion implantation into the workpiece.

12. Plasma doping apparatus as defined in claim 1 further comprising an electrode positioned at an entrance of said Faraday cup and means for biasing said electrode to suppress escape of secondary electrons from said Faraday cup and/or to suppress hollow cathode discharge.

13. Plasma doping apparatus as defined in claim 1 further comprising at least one magnet disposed at an entrance of said Faraday cup for suppressing escape of secondary electrons from said Faraday cup.

14. Plasma doping apparatus as defined in claim 1 wherein said Faraday cup has an entrance having a lateral dimension, wherein the lateral dimension of said entrance is small in comparison with a depth of said Faraday cup, and wherein a geometric configuration of said Faraday cup suppresses escape of secondary electrons through said entrance.

15. Plasma doping apparatus as defined in claim 1 wherein said chamber has electrically conductive walls and wherein said anode and said chamber are connected to a common electrical potential.

16. Plasma doping apparatus as defined in claim 1 wherein said chamber includes electrically conductive walls and wherein said anode comprises the electrically conductive walls of said chamber.

17. Plasma doping apparatus as defined in claim 1 wherein said platen is configured for supporting a semiconductor wafer.

18. Plasma doping apparatus as defined in claim 1 wherein said Faraday cup comprises an entrance aperture plate defining an entrance aperture for receiving said positive ions, an ion collector plate for collecting said positive ions, a secondary electron collector ring disposed between said aperture plate and said ion collector plate, and means for biasing said secondary electron collector ring at a positive potential with respect to said ion collector plate.

19. In plasma doping apparatus comprising a plasma doping chamber, a platen mounted in said chamber for supporting a workpiece, a source of an ionizable gas coupled to said chamber, an anode spaced from said platen and a pulse source for applying high voltage pulses between said platen and said anode for producing a plasma having a plasma sheath in the vicinity of said workpiece, said plasma containing positive ions of said ionizable gas, said high voltage pulses accelerating said positive ions across the plasma sheath toward said platen for implantation into the workpiece, a method for monitoring a dose of said positive ions implanted into the workpiece comprising the step of:

collecting a sample of said positive ions accelerated across said plasma sheath with a Faraday cup positioned adjacent to said platen, said sample being representative of a number of positive ions implanted into the workpiece.

20. A method as defined in claim 19 wherein the step of collecting a sample of said positive ions is performed with a plurality of Faraday cups disposed around said platen.

21. A method as defined in claim 19 further including the step of configuring said Faraday cup so as to minimize any disturbance to said platen caused by the presence of said Faraday cup.

22. A method as defined in claim 19 further including the step of integrating an electrical current produced by said Faraday cup in response to said positive ions with respect to time and generating an output representative of the dose of positive ions implanted into the workpiece.

23. A method as defined in claim 19 wherein the step of collecting the sample of said positive ions is performed by a plurality of Faraday cups disposed around said platen, each producing a current representative of the number of positive ions implanted into the workpiece per unit time and further including the steps of comparing the currents produced by said plurality of Faraday cups and generating an output indicative of the uniformity of ion implantation into the workpiece.

24. A method as defined in claim 19 further including the step of biasing an electrode positioned at an entrance of said Faraday cup to suppress escape of secondary electrons from said Faraday cup and/or to suppress hollow cathode discharge.

25. A method as defined in claim 19 wherein the step of collecting a sample of said positive ions is performed with two or more Faraday cups embedded in a guard ring disposed around said platen.

26. A method as defined in claim 19 wherein the step of collecting a sample of said positive ions is performed with an annular Faraday cup embedded in a guard ring disposed around said platen.

27. A method as defined in claim 19 wherein the step of collecting a sample of said positive ions is performed with an ion collector plate spaced from an entrance aperture in an entrance aperture plate, further comprising the step of preventing secondary electrons formed at the ion collector plate from moving toward the entrance aperture with a secondary electron collector ring positioned between the ion collector plate and the entrance aperture.

28. Plasma doping apparatus comprising:

a plasma doping chamber;

a platen mounted in said plasma doping chamber for supporting a workpiece;

a source of ionizable gas coupled to said chamber, said ionizable gas containing a desired dopant for implantation into the workpiece;

a pulse source for applying high voltage pulses between said platen and the electrically conductive walls of said chamber for producing a plasma having a plasma sheath in the vicinity of said workpiece, said plasma containing positive ions of said ionizable gas, said high voltage pulses accelerating said positive ions across the plasma sheath toward said platen for implantation into the workpiece; and

a Faraday cup positioned adjacent to said platen for collecting a sample of said positive ions accelerated across said plasma sheath, the sample of said positive ions collected by said Faraday cup being representative of a dose of said positive ions implanted into the workpiece.

29. Plasma doping apparatus as defined in claim **28** wherein said Faraday cup comprises a plurality of Faraday cups disposed around said platen.

30. Plasma doping apparatus as defined in claim **28** wherein said Faraday cup comprises an annular Faraday cup disposed around said platen.

31. Plasma doping apparatus as defined in claim **28** wherein said Faraday cup generates an electrical current representative of the number positive ions implanted into the workpiece per unit time and wherein said apparatus further comprises a dose processing circuit for integrating said current with respect to time and generating an output representative of the dose of positive ions implanted into the workpiece.

32. Plasma doping apparatus as defined in claim **28** wherein said Faraday cup comprises a plurality of Faraday cups disposed around said platen, each producing a current representative of the number of positive ions implanted into the workpiece per unit time and wherein said plasma doping apparatus further comprises a dose uniformity circuit for comparing the currents produced by said plurality of Faraday cups and generating in response to the comparison an output indicative of the uniformity of ion implantation into the workpiece.

33. Plasma doping apparatus as defined in claim **28** further comprising a guard ring disposed around said platen, wherein said Faraday cup is embedded within said guard ring.

34. Plasma doping apparatus as defined in claim **28** further comprising a closed loop pressure control system coupled to said plasma doping chamber for controlling the pressure of said ionizable gas in said chamber.

35. Plasma doping apparatus as defined in claim **28** wherein said Faraday cup comprises an entrance aperture plate defining an entrance aperture for receiving said positive ions, an ion collector plate for collecting said positive ions, a secondary electron collector ring disposed between said aperture plate and said ion collector plate, and means

for biasing said secondary electron collector ring at a positive potential with respect to said ion collector plate.

36. Plasma doping apparatus comprising:

a plasma doping chamber;

a platen mounted in said plasma doping chamber for supporting a workpiece, said workpiece constituting a cathode;

an anode spaced from said platen;

a source of ionizable gas coupled to said chamber, said gas containing a desired dopant for implantation into the workpiece;

means for producing a plasma containing positive ions of said ionizable gas between said platen and said anode;

a pulse source for applying high voltage pulses between said platen and said anode for accelerating said positive ions across a plasma sheath of said plasma toward said platen for implantation into the workpiece; and

a Faraday cup positioned adjacent to said platen for collecting a sample of said positive ions accelerated across said plasma sheath, said sample being representative of the dose of positive ions implanted into the workpiece.

37. Plasma doping apparatus as defined in claim **36** wherein said Faraday cup comprises a plurality of Faraday cups disposed around said platen.

38. Plasma doping apparatus as defined in claim **36** wherein said Faraday cup comprises an annular Faraday cup disposed around said platen.

39. Plasma doping apparatus as defined in claim **36** further comprising a guard ring disposed around said platen, wherein said Faraday cup is embedded within said guard ring.

40. Plasma doping apparatus as defined in claim **36** wherein said Faraday cup comprises an entrance aperture plate defining an entrance aperture for receiving said positive ions, an ion collector plate for collecting said positive ions, a secondary electron collector ring disposed between said aperture plate and said ion collector plate, and means for biasing said secondary electron collector ring at a positive potential with respect to said ion collector plate.

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